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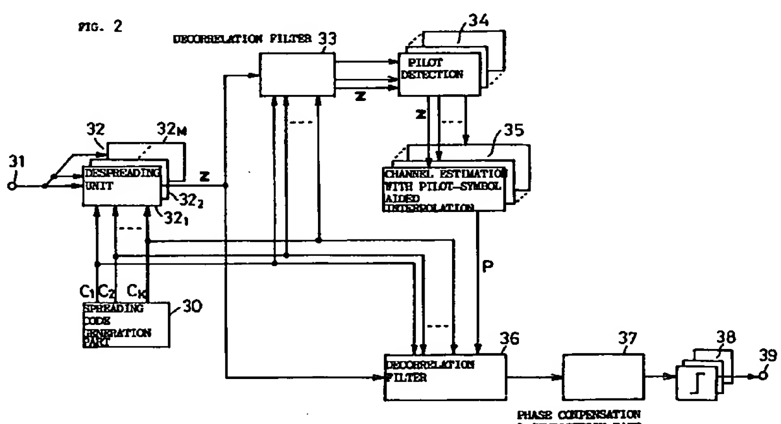
(54) METHOD AND DEVICE FOR RECEIVING CODE-DIVISION MULTIPLEX SIGNAL

(57) Each of receiving spreaded signals from K users via L channels for each user is de-spreaded with a spreading code allocated to each user. Interference components among signal components in the de-spreaded signal vector Z obtained are eliminated by a de-correlation filter (33) and pilot signals are detected by a pilot detection part (34) from the interference-eliminated signal vectors for multiple frames. Each of the detected pilot signals is divided by the pilot signal's known symbol to obtain a transfer function in a transfer function interpolation part (35) and a transfer function between consecutive pilot signals is estimated from the transfer functions of the consecutive pilot signals. A de-spreaded signal vector Z is supplied to a de-correlation filter (36) and interferences among signal components are eliminated and transmission distortion is also eliminated using the estimated transfer functions. Regarding the KL signal components obtained in the above process, L signal components corresponding to each user are composited by a phase compensation and composition part (37) so that K composite signals are generated. Those composite signals are level decided by a decision part (38) to regenerate K symbols from K users.

FIG. 2



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Description

FIELD OF THE TECHNOLOGY

The present invention relates to a method for receiving a code division multiple access signal which is applied to a mobile communications and utilizes spectrum spread, and more particularly, to a method and an apparatus for receiving M signals (M is an integer number greater than 1) from a single or a plurality of communicators (users) via a single or a plurality of channels (paths) and for obtaining a de-spreaded output which is the result of the de-correlat ion process of the received signal using de-spreading codes to eliminate interferences.

PRIOR ART

In various communication systems, studies for practical use of a Code Division Multiple Access System (CDMA) which utilizes the spectrum spread communication have been getting active because of the superior anti-interference and confidentiality of the spectrum spread communications.

One of the problems of CDMA system is so called near-far problem wherein the signal power received at a central station significantly varies dependent on the location of the user. In CDMA system, since the same frequency hand is shared by a plurality of users, the communication quality is deteriorated by interferences from the other users. For example, when a user located near to the central station and a user located far from the central station communicate at the same time, the signal power from the near user received at the central station is large while the signal power from the far user received at the base station is small. This means that the communication between the far user and the central station is significantly deteriorated by the interference of the near user.

Recently, Ruxandra Lupas and Sergio Verdu of Princeton University announced a class of linear filter which can estimate a sending signal based on a received signal from each of the users in a binary asynchronous CDMA system which receives additive Gaussian white noise. The filter of this class is referred to as a de-correlation filter. This de-correlation filter is configured using spreaded codes of each user and receiving time difference information of each receiving signal symbol and allows to estimate a sending symbol which is not dependent on each receiving signal power by eliminating the correlating components among the receiving signals to make an orthogonalization process. In addition, the processing volume of the de-correlation filter increases within the range proportional to the number of users who are communicating at the same and may not significantly increase. (R. Lupas and S. Verdu, "Near-Far Resistance of Multi-user Detectors in Asynchronous Channels", IEEE Trans. COM. Vol. COM-38, pp. 496-508, 1990).

One of the characteristics of applying CDMA system to mobile communications is that a signal corresponding to the respective channel can be separated from the receiving signal which is a composite signal of the signals passed through multiple channels in the de-spreading process. Namely, in a mobile communication environment, a signal transmitted from a sending station generally passes through multiple radio wave channels and receives respective delay and fading to reach a receiving station. If a reciprocal of band width (= chip rate) after spectrum spreading is less than the delay time difference in those channels, a correlation peak appears at the timing corresponding to the delay time of each signal received via each channel after de-spreading (this is referred to as a path separation). Since each signal receives an independent fading (phase rotation and amplitude variation), an improvement effect by diversity can be obtained by compositing the signals after compensating each phase rotation. The receiving method utilizing this is known as RAKE receiving system. In general, the more paths, the more diversity gain can be obtained.

However, the path separation function by such a de-spreading has a shortcoming as described below. What is controllable in the aforementioned transmission power control is the power of the composite receiving wave and not the transmission power of each channel. This means that the variation caused by fading still remains in the signal after the path separation. Although every signal after the path separation is a desired signal component, each receiving signal power is not controlled to be constant. Thus, the diversity effect by RAKE receiving is decreased because of the mutual interference (dependent on self-correlation characteristics of spreaded codes of desired signal) among those signals.

Further, since signals from other users are also received via multiple channels, the desired signal independently receives an interference from each of the receiving signals passed through the multiple channels of other users. As mentioned above, even if the power of the composite receiving signal wave is controlled to be constant, the variation by fading remains in the signal after the path separation. Thus, the influence of the interference to the desired signal changes in the same speed as the variation of the signal after the path separation.

A method to prevent from this shortcoming is to apply aforementioned de-correlation filter deeming each signal component of each user to be an independent interference wave. That is, for example, if K users communicate over L channels, a de-correlation filter is formed deeming LK signals obtained after the path separation by de-spreading to be the signals from independent users (at this time, the transfer function of the de-correlation filter is a rational function matrix of LKxLK). As mentioned above, since a de-correlation filter is not influenced by the differences among receiving signal powers, the influence of interference waves can be eliminated even if the signal variation remains in a signal after the path separation.

However, in this method, since a de-correlation filter is used, there is a shortcoming that Noise Enhancement associated with the de-correlation process of the receiving signal cannot be avoided. That is, the more the number of receiving signals (number of users K×number of channels L) is increased, the more Gaussian noise is enhanced at the output of the de-correlation filter. This means that when a de-correlation filter is applied to CDMA communications under multi-channel environment such as mobile communications, Noise Enhancement is increased corresponding to the number of all receiving signals rather than the number of users. This also means that the more the number of channels for the same number of users is increased, the more Noise Enhancement is increased. CDMA system has an advantage that the more the number of channels is, the more diversity gain is obtained. However, the advantage is offset by the aforementioned Noise Enhancement.

In order to cope with this shortcoming, a method for inputting a composite signal weighted by an estimated value of channel transfer function to a de-correlation filter rather than inputting each receiving signal itself is described in the literature, S. Haykin, 2nd Edition of "Adaptive Filter Theory", Prentice Hall, pp. 477-407, 1991. In this patent application, it is described that Noise Enhancement can be avoided under an assumption that a transfer function of each channel is sufficiently estimated. When CDMA system is applied to mobile communications, an adaptability to high speed fading is essential. For example, if the frequency used is in 2 GHz band and user's moving speed is 120 km/h, the maximum Doppler frequency is 240 Hz. When the channel transfer function is estimated, if a sufficient estimation for such high speed fading is not obtained, the characteristics would significantly be deteriorated.

In the method described in the above literature, each channel transfer function is estimated by a recursive estimation process such as an RLS algorithm by providing a training segment in a sending signal. Fig. 5 shows an effect of the method of the above literature obtained by a computer simulation. The following simulation conditions are used; the number of simultaneous communicators is 5, SN ratio after de-spreading is 10 dB, modulation is BPSK, and asynchronous communication environment. The horizontal axis represents f_DT which is a normalized value of the maximum Doppler frequency f_D (Hz) normalized by a reciprocal T of symbol transmission speed (bits/sec) and the vertical axis represents an average bit error rate for all the communicators. Fig. 6 shows a transmission signal format. A training signal 11 consisting of a plurality of symbols is located at the top of each frame and an information data is located between two training signals. A frame comprises a training signal and an information data and the total length is Ns symbols. For the information data symbols, the channel transfer function is recursively estimated by feeding back the result of the symbol decision and using RLS algorithm.

In Fig. 5, regarding f_DT of horizontal axis, the larger value means higher speed variation of the channel characteristics i.e., higher speed fading. The length of each training segment is 8 symbols and the frame length NS is NS=32, 64 and 128 (3 cases). The larger value of Ns means that the ratio of the information symbols to all the transmission symbols is higher i.e., higher information transfer efficiency. The larger f_DT is, the worse the error rate is. If the ratio of the information data length to the training signal length is larger, the error rate gets worse and the deterioration rate increases as the fading speed increases. In an example of an actual communication environment of f_D=240 Hz and 1/T=128 K bits /sec, f_DT is in the range of $f_DT=7.5\times10^{-3}$. As seen from the Figure, the average bit error rate is significantly deteriorated even if f_DT is in the range of $f_DT=7.5\times10^{-3}$. Such a deterioration of the characteristics is a substantial shortcoming. As mentioned above, in the conventional method wherein a channel transfer function is estimated using a recursive estimation process such as an RLS algorithm, the estimation cannot follow the channel characteristics changes in response to the high speed fading which possibly occurs in the actual mobile communications, and thus, there is a shortcoming that the characteristics are significantly deteriorated.

It is a first object of the present invention to provide a method and an apparatus for receiving code division multiple access signals wherein the deterioration of receiving characteristics is small under the high speed fading environment where the channel propagation characteristics change very rapidly.

It is a second object of the present invention to provide a method and an apparatus for achieving the above first object and for receiving code division multiple access signals wherein Noise Enhancement is less effective under the multiple channel environment.

DISCLOSURE OF THE INVENTION

The receiving method and apparatus in accordance with the first view point of the present invention are the method and apparatus for receiving code division multiple access signals wherein each frame from each user comprises an information data to be sent and a pilot signal of at least one symbol added to the top of the information data, a transmission signal spreaded by a spreading code allocated to the user is received and symbols of the information data are regenerated,

the spreading codes for K users are generated by spreading code generation means, K being an integer number equal to 1 or greater,

the spreading codes are provided to output de-spreaded signal vectors consisting of KL signal components by de-spreading each spreaded signal received from each user via L channels using the respective spreading code by de-spreading means, L being an integer number equal to 1 or greater,

an interference-eliminated signal vector consisting of mutual-interference-eliminated signal components is outputted after a de-correlation filtering process of the de-spreaded signal vector by a first inverse filtering means,

a plurality of pilot signals included in a series of the interference-eliminated signal vectors for multiple frames are detected by transfer function estimating means, and then each channel transfer function between the pilot signals is estimated from the transfer functions received by those pilot signals,

a receiving signal vector from which the mutual interference and the channel distortion are eliminated by using a transfer function matrix modified with the estimated transfer functions and by performing a de-correlation process for the de-spreaded signal vector by second inverse filtering means is outputted,

K receiving signals corresponding to the K users are outputted by performing phase compensation for each of the KL components of the receiving signal vector to composite L phase compensated signals for each user by phase compensation and composition means,

each of the K receiving signals is level decided by decision means to determine the symbols and to output them.

The receiving method and apparatus in accordance with the second view point of the present invention are the method and apparatus for receiving code division multiple access signals wherein each frame from each user comprises an information data to be sent and a pilot signal of at least one symbol added to the top of the information data, a transmission signal spreaded by a spreading code allocated to the user is received and symbols of the information data are re-generated,

the spreading codes for K users are generated by spreading code generation means, K being an integer number equal to 1 or greater,

the spreading codes are provided to output de-spreaded signal vectors consisting of KL signal components by de-spreading each spreaded signal received from each user via L channels using the respective spreading code by de-spreading means, L being an integer number equal to 1 or greater,

an interference-eliminated signal vector consisting of mutual-interference-eliminated signal components is outputted after a de-correlation filtering process of the de-spreaded signal vector by an inverse filtering means,

a plurality of pilot signals included in a series of the interference-eliminated signal vectors for multiple frames are detected by transfer function estimating means, and then each channel transfer function between the pilot signals is estimated from the transfer functions received by those pilot signals,

each of the components of the interference-eliminated signal vector is weighted with the estimated transfer function by phase compensation and weighted composition means and is phase compensated to composite the L signals for each user, and then K received signals corresponding to K users are outputted,

each of the K receiving signals is level decided by decision means to determine the symbols and to output them.

In the receiving methods and apparatus of the first and second view points, the transfer function estimating means comprises pilot detection means for detecting predetermined number of pilot signals located before and after the each information data segment of each frame and transfer function interpolation means for calculating the transfer function at the timing of the pilot signal detection and for estimating the transfer function of the information data segment by an interpolation based on the calculated transfer functions.

As described above, the receiving apparatus of the present invention is characterized in that a transfer function is estimated by means of interpolation using pilot signals in a code division multiple access receiving apparatus where a phase compensation and a weighted composition using estimated values of channel transfer functions are performed and an orthogonalization of each signal is performed using a de-correlation filter.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows an example of the code format created at the sender's side in the present invention.

Fig. 2 is a block diagram showing an embodiment of a receiving apparatus of the present invention.

Fig. 3 is a block diagram showing another embodiment of a receiving apparatus of the present invention.

Fig. 4 shows an example of relationship between average bit error rate and normalized fading speed in the present invention.

Fig. 5 shows error rate characteristics in the conventional channel recursive estimation process.

Fig. 6 shows a sender's side signal format used in Fig. 5.

BEST FORM FOR IMPLEMENTING THE INVENTION

Fig. 1 shows a signal format created at sender's side for implementing the receiving method of code division multiple access signals according to the present invention. An information data 21 to be sent is allocated to each frame and a pilot signal 22 consisting of one or several symbols is inserted into the top of each frame. A segment of the pilot signal is referred to as a training segment. Each pilot signal 22 has a known symbol value. Each frame consists of N symbols including the pilot signal.

Fig. 2 shows, for example, a receiver's side configuration of a base station. A receiving signal from an input terminal 31 is de-spreaded with spreading codes C_1-C_K corresponding to respective users at a de-spreading part 32 and is separated to a signal corresponding to each channel of each user and then outputted as a vector Z in which those signal components are arranged. For example, assuming that the number of maximum simultaneous users is K and the number of channels to be considered for the signal from each user is L, the de-spreading part 32 comprises M=KL de-spreading units 32_1-32_M, and each of the K spreading codes C_1-C_K corresponding to the respective users is provided from a de-spreading code generation part 30 at the timing corresponding to the respective delay time of each of the L channels. Each de-spreading unit can be configured as a matching filter or a sliding correlation unit and M=KL received signal components Z_1-Z_M can separately be obtained. This is identical with the path separation in conventional RAKE receiving. A KL dimension signal vector Z in which each of the path separated signal components is arranged is obtained every symbol cycle and is supplied to a de-correlation filter 33 and a de-correlat ion filter 36.

KL components of each signal vector Z supplied from the de-spreading unit 32 are inputted to the de-correlation filter 33. The de-correlation filter 33 eliminates mutual correlation components (interference components) among the separated signal components of L users caused by mutual correlation among K spreading codes in use to output a KL dimension signal vector $Z=(Z_1, Z_2,....Z_M)$. Regarding the series of signal components after the elimination of the correlation for each channel of each user, a pilot detection part 34 comprising M=KL pilot detection units 34_1-34_M detects the respective pilot signal location. A transfer function interpolation part 35 estimates the channel transfer function in the following procedure for the series of signal components of each channel of each user using the detected pilot signal.

Since the symbol value of the pilot signal is known, the transfer function of the channel through which the signal component passed can be obtained by dividing the pilot signal part 22 (refer to Fig. 1) in the series of received signal components in each channel of each user detected by the pilot detection part 34 by its symbol value. In the present invention, the transfer function in the information data segment 21 between the adjacent pilots 22 is estimated using transfer function values of the timings of the pilot signals 21 of one or several frames located before and after that segment, for example, using a first degree (linear) interpolation or a second degree interpolation. (For example, refer to a paper by Sampei "A Fading Distortion Compensation System for 16 QAM for Land Mobile Communications", Journal of Institute of Electronics, Information and Communications of Japan B-II Vol. J72-B-II, No.1, pp.7-15).

For example, in the case of first degree interpolation, if a known pilot symbol value is d, an estimated fading value is ξ, a frame number is k and Nk is a pilot signal timing, fading at the pilot signal timing is obtained by the following formulas.

$$\xi(Nk)=Z(Nk)/d$$

$$\xi(N[k+1])=Z(N[k+1])/d$$

Thus, an estimated fading value at an arbitrary symbol timing (kN+m) in an information data segment 21 is represented by the following formula,

$$\xi(Nk+m)=n\times\xi(Nk)/N+(N-m)\times\xi(N[k+1])/N \qquad (1)$$

where m=1, 2,....$N-N_P$, N_P is the number of symbols in a pilot signal segment (training segment) 22. Such a fading value obtained by an interpolation represents a transfer function of a channel through which the receiving signal passed.

The de-correlation filter 36 generates a received signal vector from which mutual correlative components among the signal components $Z_1, Z_2,..., Z_M$ and channel distortion are removed using transfer functions estimated by the transfer function estimating circuit 35 based on a received signal vector Z supplied by the de-spreading part 32. The transfer function matrix G(Z) of the de-correlatio n filter 36 is given by the following formula,

$$G(Z)=[P^H S(Z)P]^{-1}P^H \qquad (2)$$

where H represents complex conjugate transposition. P is a matrix where estimated channel transfer functions are aligned in the user basis. When each of K users has L channels, if KL=M , P is a complex matrix of M×K. For example, if L=2, then P is given as follows,

$$p = \begin{bmatrix} P_{11} & 0 & \cdot & \cdot & \cdot & \cdot & 0 \\ P_{12} & 0 & \cdot & \cdot & \cdot & \cdot & 0 \\ 0 & P_{21} & 0 & \cdot & \cdot & \cdot & \cdot \\ 0 & P_{22} & 0 & \cdot & \cdot & \cdot & \cdot \\ 0 & & & \cdot & & \cdot & \cdot \\ \cdot & \cdot & \cdot & & & & \cdot \\ \cdot & \cdot & & \cdot & & \cdot & 0 \\ \cdot & & & & & 0 & P_{K1} \\ 0 & \cdot & \cdot & \cdot & \cdot & 0 & P_{K2} \end{bmatrix} \quad (3)$$

where P_{ij} is an estimated transfer function of j th channel of i th user and is the fading complex magnitude ξ of the channel. In the formula (2), $S(Z)^{-1}$ is same as the transfer function of the de-correlation filter 33 when M=KL signal components $Z_1, ..., Z_M$ are deemed as signals from independent users, and is a rational function matrix of M×M. The de-correlation filter 36 calculates G^{-1} (Z)Z for a received signal vector Z to obtain KL signal components from which mutual correlative components (interference components) and channel distortion are removed.

Those KL received signals are phase compensated correspondingly to the delays of L channels of each user and composited at the phase compensation and composition part 37 as in RAKE receiving to obtain K composite signals. The composite signal of each user is supplied to a decision part 38 where the signal is level decided to re-generate information symbols for each user.

To perform convolution of the transfer function G^{-1} (Z) which is a inverse Z conversion of a transfer function matrix G(Z) of the formula (2) for a vector where the path separated signal components are arranged is mathematically equivalent to perform a de-correlation filtering process for the signal composited as one signal for each signal source (user) even if multiple channels exist for each signal source (user). Therefore, even if multiple channels exist, the composition result at a receiver input is deemed as one signal. A de-correlation filter is applied to this composite signal. Noise Enhancement is same as in the case where the number of channels is equal to the number of users and is not increased.

Fig. 3 shows a second embodiment of the present invention. The same reference numerals are assigned to the portions corresponding to the embodiment of Fig. 2 but the multiple blocks dependent on the number of signals are simplified to one block. In the embodiment of Fig. 2, in order to eliminate influences of mutual correlation among receiving signal components $Z_1, Z_2, ...Z_M$ for transfer functions at the timings of receiving pilot signals 22 to be obtained by the transfer function interpolation part 35, a de-correlation filter 33 is used. The process of the de-correlation filter 36 also includes a process for removing mutual correlations among receiving signals. Therefore, in the embodiment of Fig. 3, regarding the mutual correlation rem by the de-correlation filter 36 of Fig. 2 on the receivingoval process and the channel distortion removal process signals, the former process is combined into the process of the de-correlation filter 33 and the latter process is performed by the phase compensation and weighted composition part 37', and thus the de-correlation filter 36 is omitted. That is, a received signal vector Z from the de-correlation filter 33 from which mutual correlation components are removed is supplied to the phase compensation and weighted composition part 37'. The phase compensation and weighted composition part 37' is given a transfer function matrix P from the transfer function interpolation part 35 and performs a weighting on each of the inputted receiving signal vector components with the respective channel transfer function value, and performs a phase compensation corresponding to the respective channel delay as in the case of Fig.2. Then, L receiving signals of each user are composited and K composite signals for K users are outputted. Each of the K composite signals is symbol decided by the decision part 38 and K symbols are outputted.

In the aforementioned first and second embodiments, one symbol is used as a pilot signal 22. However, a plurality of consecutive symbols, for example, 2-3 consecutive symbols may be used. If a pilot signal 22 comprises a plurality of symbols, each of the pilot signals corresponding to the respective receiving symbol timing is divided by the respective known symbol value and the division result is averaged. Such a average value is obtained for each pilot signal 22 and transfer functions are estimated using these average values to interpolate between frames.

As the user moves, the transfer function of each channel varies. The higher the used frequency band is, and the faster the moving speed of the user is, the faster the variation speed. Even in such an environment, according to the

communication system of the present invention, the follow up ability can be increased by properly setting the interval of the pilot signals.

The above system can also be applied to the case where the number of users is one and the number of channels per user is one. Further, the application range of the present invention is not only for mobile communications but also for other communications.

As described above, even in the high speed fading environment where a de-correlation filter using a prior art channel-recursive-estimation-process cannot be applied, code division multiple access communications (send/receive) are possible by using the present invention.

Fig. 4 shows the characteristics of the present invention obtained through a computer simulation. The following simulation conditions are used: number of simultaneous users is 5, SN ratio after de-spreading is 10 dB, modulation is BPSK and asynchronous communication environment. The frame length is N=4, 8 and 16 (3 cases) and the length of the pilot segment of each frame (training segment) is one symbol. Comparing the ratio of the information symbols to the total transmission symbols, this corresponds to Ns=32, 64 and 128 of Fig. 5 respectively. The horizontal axis represents f_DT which is a normalized value of the maximum Doppler frequency f_D (Hz) normalized with a reciprocal T of symbol transmission rate (bits/sec) and the vertical axis represents average bit error rate of the all users. Comparing Fig. 4 indicating the characteristics of the present invention with Fig. 5 indicating the characteristics of the channel recursive estimation process, the general tendency is similar but average error rate of the present invention at the same f_DT value is two digit less than the channel recursive estimation process. Thus the simulation indicates that the present invention is excellent.

Claims

1. A method for receiving code division multiple access signals wherein each frame consists of an information data to be sent and a pilot signal of at least one symbol added to the top of the information data, a transmission signal spreaded by a spreading code allocated to a user is received from each user and symbols of the information data are re-generated, comprising steps of:

   (a) de-spreading receiving spreaded signals received at receiver's side from K users via L channels per user with respective corresponding spreading codes to obtain a de-spreaded signal vector, each of K and L being an integer equal to one or greater;
   (b) performing a de-correlation filtering process on said de-spreaded signal vector to obtain an interference-eliminated signal vector consisting of mutual-interference-eliminated signal components;
   (c) detecting a plurality of pilot signals included in a series of said interference-eliminated signal vectors for a plurality of frames and then estimating each channel transfer function between the pilot signals from the transfer functions received by those pilot signals;
   (d) obtaining a mutual-interference-eliminated and channel-distortion-eliminated receiving signal vector by performing a de-correlation filtering process on said de-spreaded signal vector based on a transfer function matrix modified using the estimated transfer functions;
   (e) performing a phase compensation on each of the KL components of said receiving signal vector and compositing L phase compensated signals for each user to output K receiving signals corresponding to said K users; and
   (f) level deciding each of said K receiving signals and symbol deciding to output them.

2. A method for receiving code division multiple access signals wherein each frame consists of an information data to be sent and a pilot signal of at least one symbol added to the top of the information data, a transmission signal spreaded by a spreading code allocated to a user is received from each user and symbols of the information data are re-generated, comprising steps of:

   (a) de-spreading receiving spreaded signals received at receiver's side from K users via L channels per user with respective corresponding spreading codes to obtain a de-spreaded signal vector, each of K and L being an integer equal to one or greater;
   (b) performing a de-correlation filtering process on said de-spreaded signal vector to obtain an interference-eliminated signal vector consisting of mutual-interference-eliminated signal components;
   (c) detecting a plurality of pilot signals included in a series of said interference-eliminated signal vectors for a plurality of frames and then estimating each channel transfer function between the pilot signals from the transfer functions received by those pilot signals;
   (d) weighting each of said interference-eliminated signal vector components with each of the estimated transfer functions, performing a phase compensation, and compositing L signals for each user to output K receiving signals corresponding to said K users; and

(e) level deciding each of said K receiving signals and symbol deciding to output them.

3. The method according to claims 1 or 2 wherein said step (c) comprises steps of:
detecting predetermined number of pilot signals located before and after each information data segment of each frame;
calculating the transfer function at the timing of the pilot signal detection; and
estimating the transfer function of the information data segment by an interpolation based on the calculated transfer functions.

4. The method according to claim 3 wherein each of said pilot signals consists of multiple known symbols, said pilot signal is divided by said known symbol value to obtain a transfer function and the average value of the transfer functions is used as a transfer function of said pilot signal.

5. The method according to claim 3 wherein said predetermined number of the pilot signals is one for each of before and after said information data segment and the transfer function of said information data segment is estimated by first degree interpolation.

6. An apparatus for receiving code division multiple access signal wherein each frame from each user comprises an information data to be sent and a pilot signal of at least one symbol added to the top of the information data, a transmission signal spreaded by a spreading code allocated to the user is received and symbols of the information data are re-generated, comprising:
spreading code generation means for generating spreading codes for K users, K being an integer number equal to 1 or greater;
de-spreading means for receiving said spreading codes and for outputting de-spreaded signal vectors consisting of KL signal components by de-spreading each spreaded signal received from each user via L channels using said respective spreading code, L being an integer number equal to 1 or greater;
first inverse filtering means for outputting an interference-eliminated signal vector consisting of mutual-interference-eliminated signal components after a de-correlation filtering process of said de-spreaded signal vector;
transfer function estimating means for detecting a plurality of pilot signals included in a series of the interference-eliminated signal vectors for multiple frames to estimate each channel transfer function between the pilot signals from the transfer functions received by those pilot signals;
second inverse filtering means for outputting a mutual-interference-eliminated and channel-distortion eliminated receiving signal vector by using a transfer function matrix modified with the estimated transfer functions and by performing a de-correlation process for said de-spreaded signal vector;
phase compensation and composition means for performing a phase compensation for each of KL components of said receiving signal vector and compositing L phase compensated signals for each user to output K receiving signals corresponding to said K users; and
decision means for level deciding each of the K receiving signals and for deciding the symbols to output them.

7. An apparatus for receiving code division multiple access signal wherein each frame from each user comprises an information data to be sent and a pilot signal of at least one symbol added to the top of the information data, a transmission signal spreaded by a spreading code allocated to the user is received and symbols of the information data are re-generated, comprising:
spreading code generation means for generating spreading codes for K users, K being an integer number equal to 1 or greater;
de-spreading means for receiving said spreading codes and for outputting de-spreaded signal vectors consisting of KL signal components by de-spreading each spreaded signal received from each user via L channels using said respective spreading code, L being an integer number equal to 1 or greater;
inverse filtering means for outputting an interference-eliminated signal vector consisting of mutual-interference-eliminated signal components after a de-correlation filtering process of said de-spreaded signal vector;
transfer function estimating means for detecting a plurality of pilot signals included in a series of the interference-eliminated signal vectors for multiple frames to estimate each channel transfer function between the pilot signals from the transfer functions received by those pilot signals;
phase compensation and weighted composition means for weighting each of the components of said interference-eliminated signal vector with said estimated transfer function, and for phase compensating and compositing the L signals for each user to output K receiving signals corresponding to said K users; and
decision means for level deciding each of the K receiving signals and for deciding the symbols to output them.

8. The receiving apparatus according to claims 6 or 7 wherein said transfer function estimating means comprising:

pilot detecting means for detecting predetermined number of pilot signals located before and after each information data segment of each frame; and

transfer function interpolation means for calculating the transfer function at the timing of the pilot signal detection and for estimating the transfer function of the information data segment by an interpolation based on the calculated transfer functions.

FIG.1

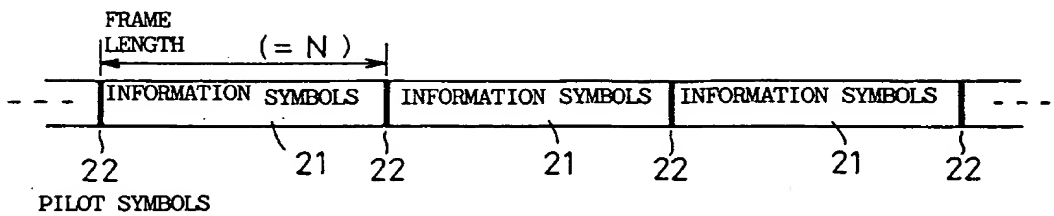

FRAME
LENGTH
(= N)
INFORMATION SYMBOLS
INFORMATION SYMBOLS
INFORMATION SYMBOLS
22
21
22
21
22
21
22
PILOT SYMBOLS

FIG.3

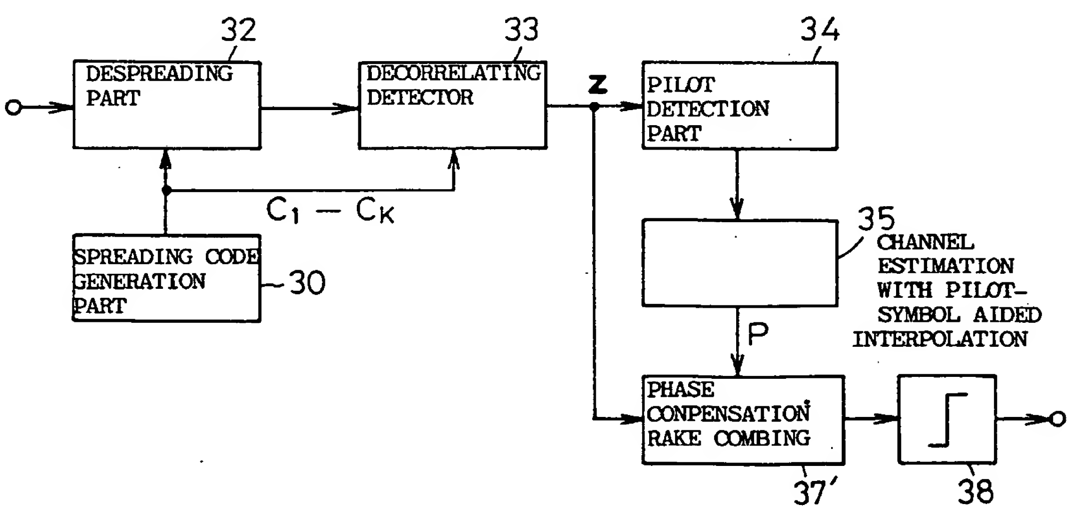
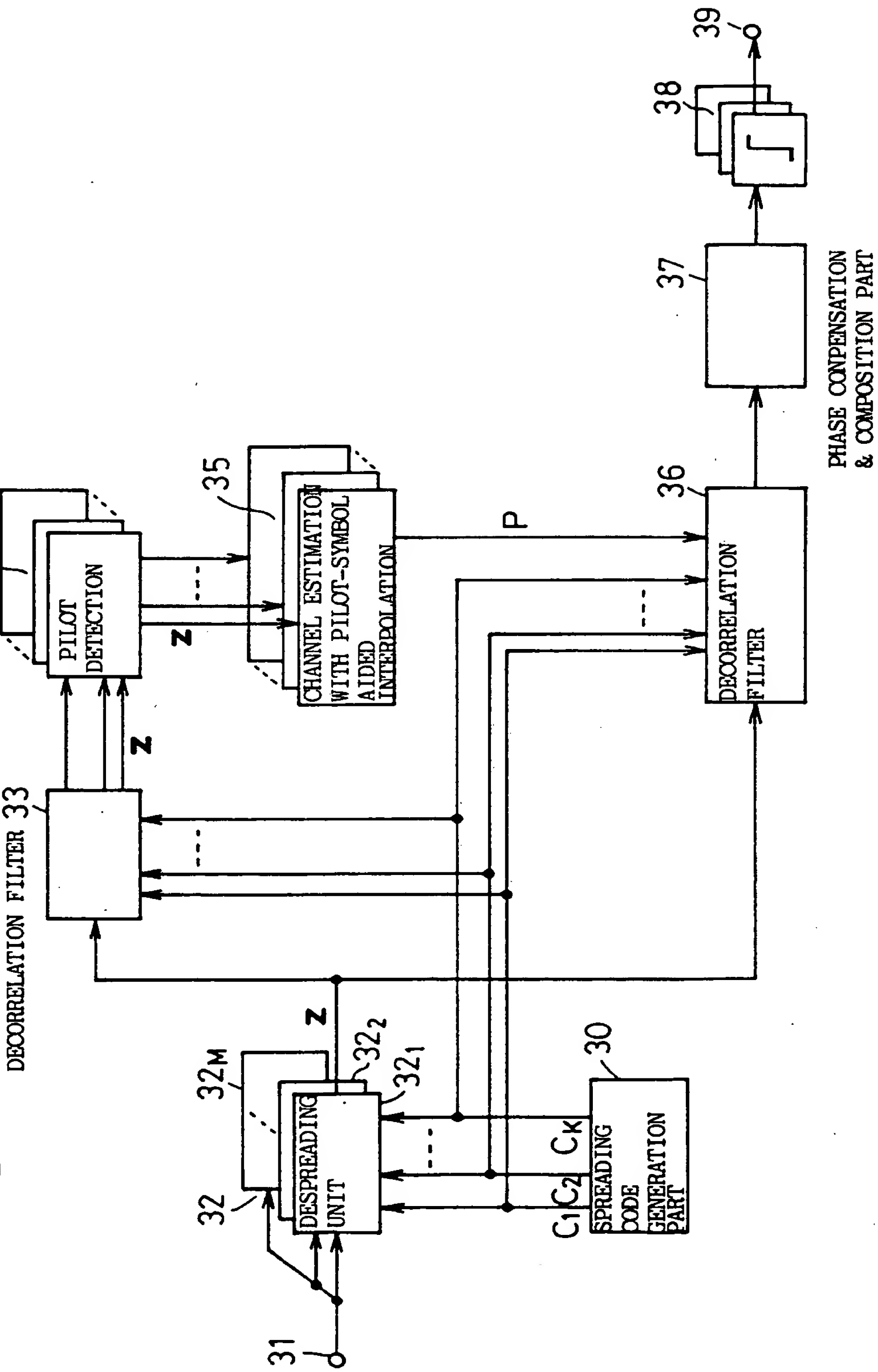

32
33
34
DESPREADING PART
DECORRELATING DETECTOR
Z
PILOT DETECTION PART
C1 — CK
35
CHANNEL ESTIMATION WITH PILOT-SYMBOL AIDED INTERPOLATION
SPREADING CODE GENERATION PART
30
P
PHASE CONPENSATION RAKE COMBING
37'
38

FIG. 2



31
32
32M
32₂
32₁
DESPREADING UNIT
30
SPREADING CODE GENERATION PART
C1
C2
CK
Z
DECORRELATION FILTER 33
Z
34
PILOT DETECTION
Z
35
CHANNEL ESTIMATION WITH PILOT-SYMBOL AIDED INTERPOLATION
P
36
DECORRELATION FILTER
37
PHASE CONPENSATION & COMPOSITION PART
38
39

FIG. 4

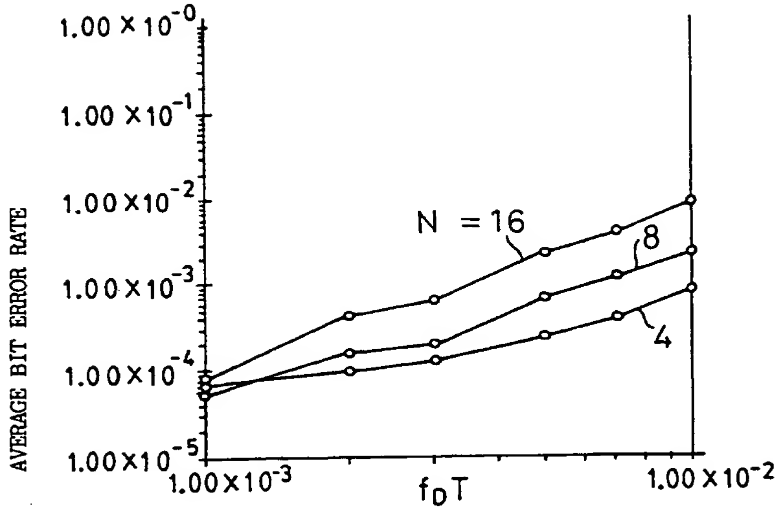


FIG. 5

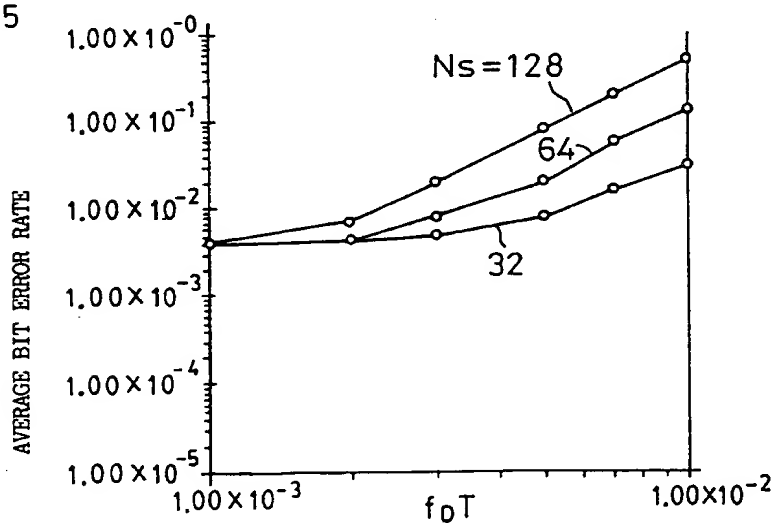
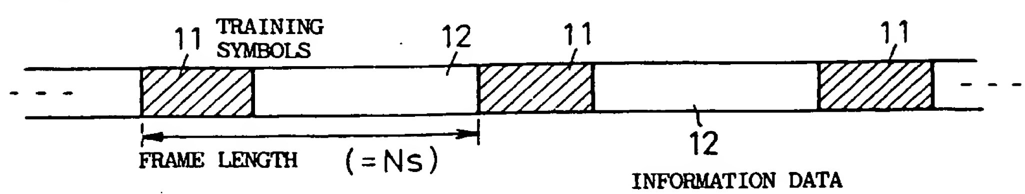


FIG. 6



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP95/01222

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl^6 H05J13/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int. Cl^6 H04J13/00-13/06, H04B1/69-1/707

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho 1980 - 1995
Kokai Jitsuyo Shinan Koho 1980 - 1995

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP, 5-227124, A (Sharp Corp.), September 3, 1993 (03. 09. 93) (Family: none)	1 - 8
A	IEICE Transaction of Spring Convention Lecture, 1994 (Vol. 2), (Lecture Nos. B-419, B-426), (1994-3), Pages 419, 426	1 - 8

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
August 22, 1995 (22. 08. 95)	September 12, 1995 (12. 09. 95)

Name and mailing address of the ISA/	Authorized officer
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